Gas Journal

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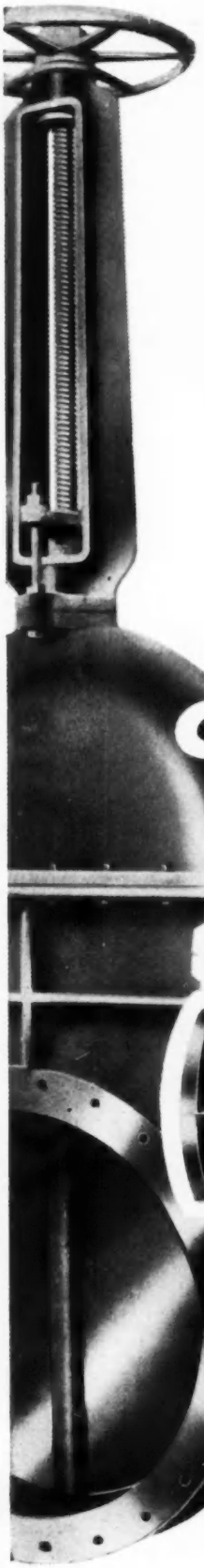

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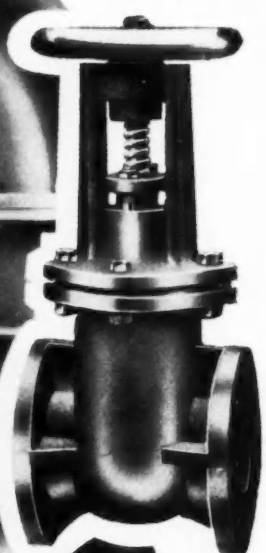

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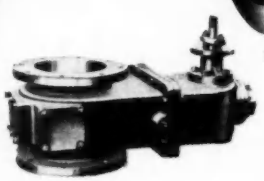

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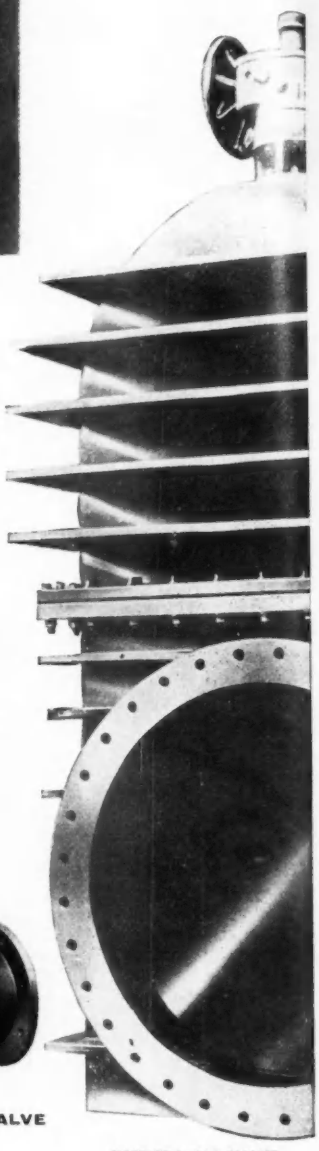

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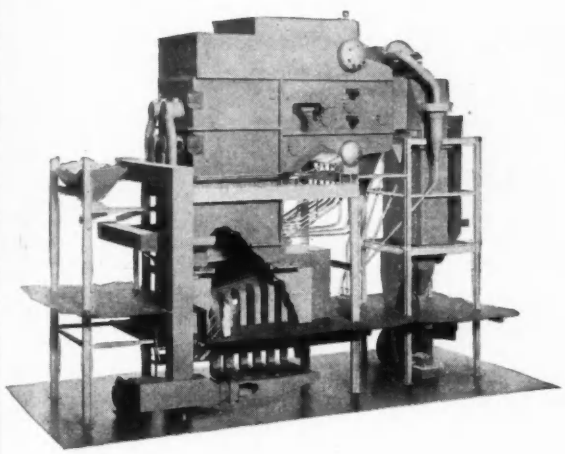

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Gas Journal

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WEDNESDAY, MARCH 22, 1961

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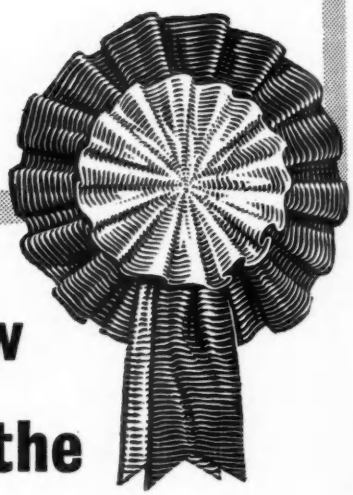

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Gas Journal

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Coke yields to Cleanglow

THE paper we are publishing this week, 'The production and marketing of Cleanglow' by Mr. C. C. Cunnold and Mr. D. G. Rose is, we think, most timely, for it helps to put the position of premium fuels in their proper perspective. Of the authors, Mr. C. C. Cunnold, a Group Engineer of the North Thames Board, was responsible for the pioneer work in Cleanglow production from low rank Midlands coals in continuous vertical retorts, and Mr. D. G. Rose, Coke Manager of the North Thames Gas Board, for organising its sales through the coal merchants soon after its appearance on the market.

So here we have the two points of view combined in one paper, the technical and the commercial. Although the former takes up the greater part of the paper, the discussion which followed showed how great is the importance of handling the sales of a new product imaginatively. This sales handling Mr. Rose has done with great skill, so that the dangerously large stocks which were building up throughout the first year of production were subsequently disposed of, and now Cleanglow is selling almost as fast as it can be loaded into the merchants' lorries. This is a most satisfactory state of affairs, especially when it is realised that other boards are making or planning to make Cleanglow.

Can we justifiably assume then that coke is no longer looked upon by the industry as a solid residue from gasmaking, from the sale of which a useful income may be derived for a reduction in the price of gas?

Coke, or by whatever name it is known, has at last been recognised as a valuable fuel in its own right, and if it is going to be bought by the general public, special types of coke may have to be manufactured for specific purposes. This is indeed a big step forward, and we are led to believe that at the new continuous vertical plant at St. Albans, coke as such is not produced, but only Gloco and Cleanglow; the very word coke is avoided to prevent there being any prejudice against the sale of these carefully controlled solid smokeless fuels. This is unfortunately completely justifiable, but it is conceivable that it might work in reverse by restoring the public's confidence in common coke, which is also carefully controlled in its manufacture at many of the industry's production stations. In this respect too the public's reaction to poor quality coke, when other solid fuels are freely available, has forced gas boards to pay more attention to ordinary coke quality.

It is interesting, however, to consider what led up to the manufacture of Cleanglow, since it would seem that the demand for an improved smokeless fuel was not directly the most important contributory factor. The primary reason for the first experiments in its production appears to have been the revised price structure for coals of different qualities introduced by the National Coal Board in 1955, by which the price of high rank gas-making coals was to rise; this applied particularly to the Durham coals used extensively by the North Thames Board. To get round this difficulty, Dr. Burns, who was then the Board's Chief Engineer, decided to try to carbonise low rank Midlands coals in existing continuous vertical retorts. The success achieved made possible not only a slight reduction in coal costs but also a far more reactive coke which the public were ready to buy. We may well ask ourselves which motive really inspired which result.

That the techniques needed to carbonise this low rank coal of considerably lower swelling number were mastered so quickly speaks well for the abilities of the Board's engineering staff, and this is borne out by Mr. L. F. Garner, Station Engineer at St. Albans, who made the point in his contribution to the discussion that after the return of one of the Eastern Board's engineers from studying the processes involved, Cleanglow manufacture had given him no trouble whatever. It would seem therefore that all the problems confronting the gas engineers of the North Thames had been solved by the consideration of the fundamental issues involved from first principles. With the solution achieved it would be easy to formulate the necessary techniques.

Having considered the actual production of Cleanglow, it does seem to us that the whole question of the production of high grade smokeless fuels, which are really substitutes for bituminous coal and anthracite, raises the question of what is going to be the future policy of the gas industry towards solid smokeless fuels.

As we have stressed on more than one occasion, the

tendency is growing for the proportion of gas produced to solid residue available for sale, to fall. This has undoubtedly been brought about by difficulties in the sale of the ordinary grade of gas coke and the ever increasing cost of good gas-making coals. The kind of solution being sought is the substitution for coal of oil or refinery gases—or even natural gas in the foreseeable future—and the total gasification or hydrogenation of low rank coals in plants of very high capacity.

Clearly those fortunate enough to be on a gas supply may well prefer to use the latest gas-fired room heater with all its attendant advantages. Should this happen, presumably the high load factor on the big central plants will help to reduce the price of gas.

Is the gas industry going to make a special effort to provide a large tonnage of Cleanglow for those in country districts outside the range of a distribution system, or leave it to the N.C.B.? Clearly this may be looking some distance into the future, but we feel that the decision will eventually have to be taken by the industry. In the meantime will it be necessary to convert each vertical retort installation throughout the country to the production of Gloco or Cleanglow—or perhaps both according to the time of year—if coke is to be sold in any quantity until the new gas-making processes are perfected and are supplying the bulk of consumers' demands?

This may well be the short-term solution, and for those boards which possess only static plant it may well be necessary to manufacture a dense coke for the export market—if it has not been captured by oil or l.p.g. shipped from the world's oil distilleries—or perhaps a coke of the Sebrite type now made by the South Eastern Board.

We see then the possibility in the long-term of the Coal Board manufacturing the major proportion of the solid smokeless fuel either in ovoid form or by some smoke-extracting process by which coal is rendered smokeless but at a low enough temperature not to interfere with its free burning qualities.

Whatever the future may bring it is quite clear that a Cleanglow type of fuel is here to stay until some better type of fuel becomes available. The premium price seems unimportant in a slightly more affluent society, but its quality must be maintained or else it may well go the way of 'common' gas coke.

The future of warm air heating

ANY contribution to our knowledge of space heating by gas is always welcome, and this is especially so when it comes from someone employed in the industry rather than a heating and ventilating engineer or a technologist from the appliance manufacturers. It shows that the industry is fully alive not only to the need to develop space heating as a permanent load to increase the domestic consumption of gas, but that it trains its engineers how to go about advising, and possibly installing, the more elaborate ducted air systems.

In a paper read recently to the Yorkshire Juniors on 'Space heating by ducted air,' the author, Mr. D. M. Brear, Industrial Technical Assistant to the Wakefield Group of the North Eastern Gas Board, gives a most detailed account of this particular form of whole-house heating.

The increasing demand since the end of the second world war for a more comprehensive system of space heating has been most marked; it may well result from the influence of the military forces from North America, especially the Canadians who spent so much of the war in Great Britain. This is Mr. Brear's view, but whether right or wrong it is certainly remarkable how quickly the idea caught on once the technical problems of the proper size for the heat exchangers for individual gas fires had been found, and the best means of heating and circulating the warmed air in the surprisingly compact centralised systems had been worked out.

Mr. Brear describes in same detail the calculation of the volume of heated air needed for a given ducted air installation and also shows how the cross section of the ducts must conform to certain dimensions, if the quantity of heat carried is to be properly and uniformly distributed. He also describes the types and size of the grills and register through which the air leaves and enters the room respectively.

Clearly the chief drawback to any system of this type is that the amount of structural alteration needed when installing it in an existing house often makes it only applicable to new houses; even then the necessary modifications must be incorporated in the design stage when the architect is getting out his overall blue prints for, perhaps, a new housing estate. But the paper is more reassuring in that in some of the layouts given by the author, background heating, at least, may be possible from a centralised air heating appliance installed in a cupboard in some central position in an existing house. This is indeed encouraging since we feel sure that if this form of heating was put over properly to the younger generation of householders, it would meet with a good measure of acceptance. The fact that it can be controlled thermostatically ensures that no fuel is wasted, and the principle of the correct number of air changes helps to maintain a high standard of comfort with the most healthy and hygienic conditions.

As far as the gas industry is concerned it must give those interested in selling gas some pleasure to be reminded that gas, and gas alone, appears to be the fuel used exclusively in the heating units. We have not heard of electric heaters being used and we feel sure that so small an appliance would be quite unsuitable for oil burners.

We are grateful to the author for bringing this type of heating to our notice at this particular time since we understand that in North America, the home of central heating, and in Canada in particular, the idea of 'wet' central heating—by conventional hot water radiator—is now old fashioned, and ducted heated air is considered the *dernier cri*. This is where gas might really come in.

From a paper read to the London and Southern Section of the I.G.E.

The production and marketing of Cleanglow

By C. C. CUNNOLD, A.M.I.C.E., A.M.I.GAS E.,
GROUP ENGINEER, NORTH THAMES GAS BOARD,
and
D. G. ROSE, B.SC.,(ECON.), F.S.S., M.I.GAS E., M.Inst.F.
COKE MANAGER, NORTH THAMES GAS BOARD.

THE introduction at the beginning of 1955 of the idea of using coals of the rank and type sold at that time by the National Coal Board under the industrial price formula, was against a background of a shortage of traditional gasmaking coal and an increasing differential in price between coal sold on the industrial formula and that sold on the carbonisation formula.

On the technical side the introduction was against a background of a long tradition of gas manufacture in continuous vertical retorts from high rank Durham and Yorkshire coals with high swelling indices and a high yield of gas per ton of coal.

The introduction, too, was against a background of the necessity to produce a reactive type of smokeless fuel which might be more attractive to the domestic user than the coke produced from traditional coals. One of the disadvantages of the coke from traditional coals was its high ash content and this, coupled with the fact that transportation charges for this low rank coal from the East Midlands would be high, pin-pointed the need at the very start of the trials for a coal with the lowest possible ash content.

Preliminary trials

Preliminary trials with samples of coal to meet the requirements of rank and ash content illustrated immediately the low gas yield per ton of coal, but demonstrated the necessity of altering carbonising technique from that to which the Board had become accustomed with the traditional coal to compensate for this gas loss. At the same time, the preliminary trials showed that the smokeless fuel produced was more reactive than traditional coke.

The North Thames Board foresaw the possibilities of this type of carbonisation and then proceeded to more intensive full-scale trials using different descriptions of coal at Bow Common, Kensal Green and Romford,

The trials showed that (a) a gas of suitable quality could be produced from low rank coals, (b) the throughput of coal and the therms per retort were increased, (c) a free burning coke was produced of such quality that it could be used in a stool bottomed grate, and (d) the costs of production with the existing net return per ton of coke were no more than with Yorkshire coal and with an increased return from coke the cost would be lower.

The Board therefore considered it opportune to develop the carbonisation of low rank coals on a commercial basis, and in 1956 decided to market the resultant coke under the trade name of Cleanglow.

Table 1 shows the broad specification of the coals needed.

TABLE 1

Rank	701 to 901
Size	in the region of 3½ in. by 1½ in.
Ash	in the region of 3½ to 4%
Swelling index	1½ to 3
Sulphur	reasonably low
Price	industrial formula

The National Coal Board indicated that the coalfields in the East Midlands would be the most suitable to meet our specification; furthermore this division is geographically suitable for our railborne supplies.

Agreement with the N.C.B. was reached to supply 4,800 tons per week, and in October, 1956, full scale production commenced at Ascot and Lea Bridge works using the following description of coal:

Warsop High Hazel/Main bright W. mixture 3½ in. by 1½ in.

Rufford Top Hard W small nuts 2½ in. by 1½ in.

Thoresby Top Hard W small nuts 2½ in. by 1½ in.

Whitwell Hazel W.D. nuts 2 in. by 1 in.

Whitwell Hazel W Treble nuts 3 in. by 2 in.

These coals were successfully carbonised and produced good quality Cleanglow.

The Board's total allocation now amounts to 14,000 tons per week producing approximately 6,000 tons of Cleanglow.

Production basis

Cleanglow production is based on increasing the throughput to the maximum, consistent with clean discharges, while maintaining combustion chamber temperatures at their normal level. The additional throughput over that normally obtained with Yorkshire gas coals depends mainly on (a) the swelling property of the coal, (b) the grading of the coal, and (c) the cross sectional area of the retort.

Generally speaking, the smaller retort produces the highest differential in throughput and a more precise control can be exercised over the rate of extraction than is possible with the large retort. This has been particularly demonstrated on the 33-in. Glover West retorts at

Stratford, where initially, throughputs of 65% over normal were recorded. This compares with throughputs of 35% over normal obtained on the 82-in. Woodall-Duckham retorts at Bow Common.

As a result of the high throughput the apex of the coal core is brought down much closer to the extractor than in normal carbonising practice. Therefore, relatively small changes in the coal travel produced by variations in the grading and swelling properties of the coal, and/or variations in retort temperatures, may give rise to either 'green' or over carbonised discharges.

Continual and careful supervision of coke discharges is therefore essential, so that any variation in quality of the Cleanglow is quickly detected and corrected by adjustment to the rate of extraction.

Clearly, it is an advantage to use coals of uniform grading and possessing similar swelling properties in any particular unit. Optimum results will be obtained from 82-in. W-D retorts when using doubles with a swelling number of 2½ to 3. The Glover West 33-in. and 40-in. retorts are more flexible in this respect, although when carbonising coals of mixed grading and varying swelling numbers a greater degree of care is necessary in the control of carbonising conditions.

Temperature control

Strict control of temperature is clearly vital in the production of Cleanglow. Using low rank coals with moisture contents ranging from 9 to 15% at high throughputs, demands an adequate supply of producer gas. Any falling off in the supply of either quantity or quality will obviously quickly affect retort temperatures, particularly in the upper zone of the retort where it is essential to maintain adequate temperatures in order to dry the coal before it reaches the carbonising zone.

The successful production of Cleanglow depends on the selection of the optimum carbonising conditions and their maintenance to an extent even greater than in traditional carbonising practice.

The calorific value of the purified gas produced is normally within the range of 500 B.t.u. to 530 B.t.u. per cu.ft. dependent upon the grade of coal used and prevailing carbonising conditions. Steaming is usually limited to 5 to 6% inclusive of the steam produced from the coke box water sprays.

High steaming rate can only be achieved at the expense of Cleanglow quality, since in order to obtain a reasonable efficiency, coal throughput must be reduced. Furthermore, it is uneconomic to produce water gas from a premium priced fuel, so it is preferable to provide a diluent gas for calorific value control from external sources.

Low rank coals normally produce a yield of 65 therms per ton at 500 B.t.u. per cu.ft. On a basis of 40% increase in coal throughput over normal, and compared with a yield of 80 therms per ton from Yorkshire coal, the volumetric and thermal output will be increased by approximately 14%.

The sulphur content of low rank coals is usually higher than in the Yorkshire gas coals, so the H_2S content of crude gas may range from 600 to 1,200 grains per 100 cu.ft., and the organic sulphur from 25 to 40 grains per cu.ft. This and the increase in gas output cause an increased loading on the oxide purifiers and sometimes an undesirably high content of organic sulphur in the district gas. Benzole plants, where available, are operated to give maximum organic sulphur reduction, and consideration is now being given to the introduction of sulphur extraction plants at two of three of our largest Cleanglow stations.

With the exception of Ascot works, the Cleanglow stations use either Beckton furnace coke, or horizontal cokes imported from other stations, in the producers. At Ascot, however, because of the high transport costs of importing other cokes, Cleanglow nuts (½ in. by ⅜ in.) are used in the producers. The use of this grade of fuel is restricted to settings fitted with a common producer gas bus main with vertical uptakes which can be kept free of dust. The fuel consumption at Ascot is a little higher than at other Cleanglow stations, being 10.6% of the coal carbonised, compared with 9 to 10%. The lower figure at Bow Common of 8.75% is due to the improved heating system and better insulation of the external walls of the settings.

The Ascot station carbonises 100% Gedling Hazel washed doubles with a moisture content of 14.6%, and to do so successfully demands the maintenance of higher top temperature conditions. The thermal yield per ton of coal is low, but this is offset by its lower cost. The yield and quality of the Cleanglow is satisfactory.

When Bow Common was placed on Cleanglow production it was clear that the 82-in. retorts with continuous minor axis taper would cause difficulties in the control of extraction when carbonising small coals of low swelling characteristics. The choice of coals was limited, and in order to meet the tonnage required, nine descriptions of coal of double grading were accepted. The control of carbonisation is therefore exacting, and particular care has to be taken to avoid raw coal in coke discharges.

Control of coal travel in the 33-in. retorts at Stratford was excellent and throughputs of over 65% above normal were obtained, but heavy spalling was taking place, particularly during scurfing, although the retorts had completed only about two years' work; up to this time they had shown little or no wear. The cause was shown to be the high alkali content of the low rank coals. An analysis of the various coals used showed that Whitwell contained the smallest alkali content at .46 to .5% and Thoresby the highest content at 1.26 to 1.31%. When the station resumed Cleanglow manufacture in October, 1958, only Whitwell coals were used. Working temperatures were reduced and the throughput adjusted accordingly.

Scurfing technique

Modifications to the scurfing technique have helped to arrest further deterioration, but the damage already done does, at times, give rise to erratic coal travel in certain of the retorts. Retorts built in siliceous material are therefore now regarded as unsuitable for the carbonisation of low rank coals, and at the next resetting these retorts will be constructed in silica.

Lea Bridge station carbonises 12 descriptions of coal comprising 60% doubles and 40% singles with swelling characteristics ranging from 1 to 3. Under such conditions carbonisation demands a high standard of supervision to ensure the production of a consistent quality of Cleanglow.

The high proportion of singles coal used is reflected in the lower yield of Cleanglow and the higher percentage of 1-in. to ¾-in. size in the product.

Five tests on Cleanglow from this station showed that the second and third radiation peaks were lower than those of the other stations. This is attributed to the flocculent nature of the ash produced by certain of the coals used.

At Slough, 100% singles of two descriptions of coal are carbonised. Here again, there is a reduction in the Cleanglow production, and a higher percentage of the 1-in. to ¾-in. fraction. The thermal results have been affected to some extent by the poor condition of the retorts in one of the three benches.

Effluents have posed a problem at those stations operating liquor concentration plants. In addition to an increase

in liquor volume, the fixed ammonia salts have risen by 40%, the O/A characteristics have increased from 10,000 to 14,000 ppm., and the polyhydric phenols from 4,000 to 7,000 ppm.

Segregation of the retort house liquor will result in some improvement by restricting the bulk of the liquor from contact with polyhydric phenols and fixed ammonia salts.

Because of its friability, the handling of Cleanglow liberates dust particles contained within its cellular structure, so special measures to suppress the emission of dust are essential. Fortunately at the Board's stations manufacturing Cleanglow, with the exception of Ascot, the retorts are equipped with dust extraction at the coke extractors. Combined with water spraying the retort coke chambers, this reduces dust emission to the minimum.

At the time the trials of low rank coals were carried out, many tests were performed on the cokes produced at Watson House under the direction of Dr. F. J. Eaton. From this work, it was possible to evolve a broad specification for Cleanglow quality, and manufacturing stations were required to conform, as far as possible, to the limits shown in Table 2.

Moisture content

The stations aim to maintain moisture contents between 6 to 8%. Contents below 6% will give rise to excessive dust emission on handling the coke, which is objectionable to both producer and consumer. High moisture figures are obviously undesirable since the ignition time may be increased and the recovery rate on refuelling the fire impaired.

Although the ash content has little influence on ignitability, the low ash figure of Cleanglow is an attractive feature to the consumer because it reduces his work to the minimum. There are certain coals, however, which produce an ash of a flocculent type. The cokes from these coals may give satisfactory ignition times, but the ash will cause banketing of the fire, and on replenishment recovery will be slow which will result in unacceptable peak radiation values.

Reactivity of the fuel, as measured by the ignition time, is a function of the following factors: (a) Carbonising conditions, (b) bulk density, and (c) grading. To a very limited extent, carbonising conditions can be assessed from the volatile therm content of the coke—figures of 7 to 9 therms per ton are regarded as normal for Cleanglow. The bulk density of Cleanglow is approximately 20 lb. per cu.ft. and is similar to that of cokes produced from Yorkshire coals.

In the matter of grading, it is only necessary to remove the material below ¼ in., as the average proportion of Cleanglow over 2 in. does not usually exceed 12%. In the carbonising of low rank coals, agglomeration in some degree does occur if a proportion of the coal has been obtained from Hazel Soft seams, but the coals from Top Hard seams produce cokes which are largely a reflection of the sizing of the coal as charged to the retorts.

For this reason, and the fact that the coke handling and grading plant arrangements vary between stations, it has not been possible to standardise at the stations the mesh of main screens, and each station has had to determine the mesh sizes of the screens to suit their particular conditions in order to meet the recommended grading limits.

As a control of quality, it is essential to carry out regular fire performance tests. It is the practice at all Cleanglow stations to take daily samples as it is loaded into customers' sacks or vehicles. A proportion of the daily sample is retained to form a composite weekly sample. The former sample is tested each day for ignition time, grading and moisture content, and a full fire test is performed on the weekly sample. The latter test is carried out in a 'London' fire using the standard procedure laid down in the Gas Council Report on Coke Quality—using 4,000 B.t.u. for ignition instead of the standard 7,000 B.t.u.

Although a Cleanglow may meet all the requirements of the specification, it is still possible to get complaints from the customer. The customer tends to judge a fuel very largely on its appearance and if the fuel appears to him to be small in size or contains what he believes to be shale, he will complain.

The low rank coals mined from top hard seams are a mixture of dull and bright coals, usually in the proportion of 2:1. The dull pieces have rather a shaley appearance and this is, to some extent, reproduced in the cokes. If this is over evident in the Cleanglow, a complaint is almost certain to arise, although the fuel may give a satisfactory fire performance. An example of this occurred at one station where a proportion of trebles was carbonised. The dull pieces of this coal were unchanged in size after carbonising, and produced a coke of markedly shaley appearance which could be readily picked out. By reducing the grading of the coal, the appearance of the coke was much improved and complaints of shale reduced to a low level.

TABLE 2

	Mean value not to exceed	Limiting value	Mean weekly range
Moisture %	7	10	6
Undersize below 1 in. ..	15	20	—
Undersize below ¼ in. ..	5	8	6
Ash %	7	7·5	—
Ignition time, minutes ..	26	33	8
3rd peak, B.t.u/sq. ft/hour ..	—	550*	—

*With the best Cleanglow, the 3rd peak can reach values greater than 800 B.t.u/sq. ft/hr and it is desirable that in normal production the 3rd peak should not fall below 600 B.t.u./sq. ft/hour.

Perhaps the most important finding from the long-term point of view of the gas industry which came from a survey of the changed pattern of fuel usage in some smoke control areas within the North Thames Board's area was that seven out of eight of the householders were pleased with the change.

Snowball growth

Cleanglow was introduced in 1956, the year in which the Clean Air Act was passed. Like progress under the Act, Cleanglow itself got off to a slow start; but the two are closely related and the formation of smoke control areas, apart from the clean air movement generally, now shows signs of snowball growth, just like the demand for Cleanglow.

In 1956 time was ripe for the introduction of a premium smokeless solid fuel by the gas industry. The past decade had brought full employment and a modest affluence which in turn brought demand for better living and luxury consumer goods. In the social sphere there was an increasing demand for clean air, clean food, a cleaner and physically healthier way of life. Cleanglow could well go down as a classical example of a commodity introduced at the psychological moment; but it provides also an interesting example of the inter-relationship of ideas springing from engineering and commercial departments. As the paper shows, there were teething troubles, but the venture has

been a successful one from both production and marketing points of view.

Demand for Cleanglow is well in excess of the output, and there are limitations on its rate of development, but the fact that the gas industry has responded to a public need in this particular way should surely encourage those engaged in the search for other smokeless solid alternatives to raw coal as used in open fires—whether they employ carbonisation or some totally different process.

The early fears expressed by Cleanglow critics have not been realised. No odious comparisons have been made between Cleanglow, the premium fuel, and Gloco, the quality open-fire coke. Each finds its own market naturally and easily on the age-old buyers' acceptance of the principle that 'if one wants a better article one must pay more for it.' In the marketing of Cleanglow it is apparent that in the present buoyant economy, price is not necessarily the limiting factor to the sale of a quality fuel. People are prepared to pay more for a good product provided it gives them what they want.

It was queried also whether the Board had been right to entrust distribution entirely to the trade instead of selling direct. These doubts also have long since been dispelled.

The records of Cleanglow production and sales confirm that the correct assessment of market conditions had been made in 1956. Production by the Board has quadrupled in four years, and each year provides a growing demand calling for additional supplies to meet it. Three other area boards, with North Thames approval, are using the name for products conforming to the Board's specification. Including these, the total output is now approaching .5 mill. tons a year, and several other area boards are known to have the manufacture of Cleanglow under active consideration.

The conception of Cleanglow marketing was that it should be made generally available throughout the Board's traditional area for coke distribution, that is to say over the whole of the North Thames gas area and into Greater London outside it. The rail facilities outwards which existed at Ascot and Lea Bridge were additional reasons for choosing these stations for the initial regular production of Cleanglow. Both works had highly satisfactory local markets for their coke, so one of the first problems was to provide from elsewhere an alternative supply of suitable coke for sale in the surrounding districts as well as for works use. Much of this coke, of course, passed Cleanglow going out for more distant markets.

Wide marketing area

The wide geographical area over which the initial marketing of Cleanglow took place from only two centres was one of the reasons for the Board's decision to market the fuel through its Authorised Coke Distributors. It will be appreciated also that, Cleanglow being intended for coal substitution, it was felt right that merchant distributors should be given the first opportunity of selling it on behalf of the Board. Furthermore, as with coke, the merchants' existing depot organisation represents a facility for local distribution.

Confident in the new fuel, certain distributors were canvassing in Fulham as enthusiastically as any piped fuel salesmen, even though some may have been opposed on various principles to clean air legislation. The moral to be drawn by any who doubt the ultimate support of the distributive trade in smoke control area development is, once the decision has been finally taken, the merchants are as keen as any other fuel salesmen to provide the service required. Fulham No. 1 is an honest-to-goodness clean air zone, involving mostly terraced houses which required complete conversion of the old appliances, and on experience to date no zone could have proved more successful. Complaints against local delivery service have been very few indeed.

We may fairly regard Cleanglow as an example of a product which has built up its own excellent market on a quality reputation it has established for itself. Those on the sales side are very conscious of the fact that, for their colleagues responsible for production, the maintenance of a consistently high standard of quality is not an easy matter but one which requires vigilance day by day. They can also see that a lowering of quality could have very damaging results. It is essential that behind the sales effort there lies a thorough control of Cleanglow quality, as outlined in this paper, and without which no sales organisation could be effective.

DISCUSSION

Dr. J. Burns, Deputy Chairman, N.T.G.B., said that they had to go back to 1955 to see how the manufacture of Cleanglow had started. In that year there had developed the coal price structure, by which the price per therm of carbonising coal would have been higher than the price per therm of industrial coal. The gas industry found it would have to pay more for its coal, and those boards carbonising Durham coal, a higher price still. Clearly something had to be done about it, so it was decided to carry out extensive experiments on the carbonisation of industrial coal, and 15 tons were brought to Bow Common gasworks for this purpose from the Midlands. Clearly there was little point in transporting large quantities of ash from the coalfield, so a coal with the minimum ash content was specified. This 15-ton sample had been passed through the retort house, and from the information obtained, it had been possible to expand their ideas on the prospects of being able to make full use of this type of coal in quantity. A few months later the Board had been informed and permission granted for gaining all the necessary information about its use and full operational details. In a relatively short time they had determined the optimum throughput, temperature control, and other details.

Dr. Burns paid tribute to the hard work of the stokers and engineers who watched over the work with such great interest and devotion.

They had in fact found that more gas and not less was obtained from this type of coal than from conventional carbonising process, but they would really have achieved nothing without the co-operation of people like Mr. Rose, the Board's coke manager. Dr. Burns might tentatively have suggested a premium charge of 10s. a ton, but Mr. Rose's reply had been that with 30s. more a ton they might get somewhere.

The National Coal Board's reaction had been one of acclaim for another market for coal. The East Midlands Division of the Coal Board had been very helpful, and Dr. Burns paid tribute to the assistance given by Mr. T. C. Finlayson, of the Woodall-Duckham Company, from his very great experience of carbonisation, but stressed the need for a thorough testing of all coals for the production of Cleanglow to a rigid specification.

Later the Coal Board had seen that there was danger of the gas industry entering its domestic market, and had regretted its decision of complete co-operation, but it had eventually relented and allowed coal to be released, since it had realised that if this coal was not used for Cleanglow, the market might be lost entirely. The quantity of this type of coal now used by the Board amounted to some 1.25 mill. tons annually.

In the first year of manufacture, Cleanglow had piled up at Bromley gasworks, and had reached the disturbing

amount of between 30,000 and 40,000 tons. The Board has always had a great belief in Cleanglow, and thanks to the efforts of its marketing organisation, all stocks had been dispersed and production was now sold without delay.

Mr. L. F. Garner, Eastern Gas Board, St. Albans, said that as a result of one of their engineers being given the opportunity to study operational conditions at Lea Bridge works, and his report on the techniques involved, a start had been made on the production of Cleanglow at the new West's installation at St. Albans. There had been no difficulties whatsoever in changing over from normal working to Cleanglow manufacture. The heat input to the settings had been increased and the coal throughput speeded up to hold the flue temperatures steady. Ultimately such factors as the capacity of the exhausters and the waste heat boiler fan motors had more or less settled the coal throughputs. By this time the air flow to the mechanical producers had been increased from 49,000 cu.ft. per hour to 63,000 cu.ft. per hour and the coal throughput from 6 tons to 8.6 tons a day.

It was now necessary to empty the bottom coke chambers six times per shift instead of the normal four times and quenching water supplies had had to be increased and steam to retorts reduced. There was now more work in keeping the retort house clean, but any previous difficulties with coal travel had quite disappeared.

Daily sample test

The ample supply of good producer gas from the mechanical producers had probably contributed to the smooth working, but their experience at St. Albans was that the production of Cleanglow was a very easy operation.

A daily sample of the Cleanglow made was fully tested in the central laboratory at Tottenham and data relating to moisture, ash, volatile matter, screen analysis, bulk density, ignition time and fire performance was telephoned to St. Albans daily and reported to the divisional engineer and area coke manager weekly. Additional moisture and screening tests were also carried out at St. Albans. As a result of this close control complaints from customers had been practically nil and the demand has been increasing rapidly.

Apparently in common with Lea Bridge, however, they had had some difficulties at times with low third radiation peaks presumably due to flocculent ash; and he noticed that both works used Mansfield, Warsop, Oxcroft and Thoresby coals. Perhaps they worried about this more than their customers.

He noted that the different works varied the size of screen mesh used in order to produce the required size of product; he considered this to be so much more sensible than obstinately passing the coke over specified standard mesh screens and then complaining that the coke in the bags was not the right size. Referring to working results he quoted the following figures from the plant at St. Albans which consisted of 64 50-in. Glover West retorts.

Volume of gas made per ton (cu.ft.), 12,422.
Calorific value, 536.
Therms per ton, 66.5.
Therms per retort per day, 573.
Throughput, tons per day, 8.6.
Producer fuel (wet), 10.3%.
Temperature, No. 3 pass, 1,300°C.
Top, 1,030°C.
H_2S inlet purifiers, 650 grains/100 cu. ft.

A trial run carried out some months ago had given the Cleanglow yield as 8.03 cwt. per ton, while the figure for Cleanglow actually sold since October was 8.12 cwt. per ton.

Referring to the costs quoted in Appendix 4 of the paper, he asked whether it was correct to assume that all figures related to coal as purchased and coke as sold; the variations in moisture content could easily change the appearance of figures completely. If maintenance costs for resetting and retort house repairs were assessed on a fixed rate per ton of coal carbonised, the cost per therm when producing Cleanglow would be higher. A charge of an additional .25d. per therm under this heading would amount to approximately £12,000 per annum more at St. Albans. The actual charge would seem to be less than this, but should this be so, the case for Cleanglow would be even greater than that set out by the authors in their excellent paper.

Mr. C. A. Deas, Coke Manager, Eastern Gas Board, stressed the topical interest of the paper in that it applied not only to smoke control areas where householders had no alternative than to burn one or other of the smokeless fuels, but to other urban districts, in particular new towns, where there was an increasing recognition by the public at large, of the merits of clean air; this was confirmed by the steadily increasing demand for both Cleanglow and Gloco. Provided the quality of these fuels could be maintained there was little doubt that there should be a steady expansion in sales of the industry's solid smokeless fuels into the domestic market.

In addition to the broad specification for the coal necessary for the production of Cleanglow given in the paper, there was the need to avoid coals containing shale, since this appeared as stony pieces of incombustible matter in the residue in the grate after the fire has died out, or, worse still, causes 'spitting' from the fire.

The successful marketing of both Cleanglow and Gloco could be far more seriously affected by the presence of shale, particularly in large pieces which remain on the fire bars, than the failure of the fuel to attain the specified third peak or because it contained perhaps 1% or 2% more ash than the figure recommended by the authors. This specification for coal should include a nil provision for burnt shale, i.e., shale remaining in the fireplace; this was not an impossible standard, but it did mean careful selection of coals to be used, and the full co-operation from the N.C.B. in maintaining coal quality.

High rate of travel

Referring to the need to maintain a high rate of travel through the retorts as an important factor in the successful production of Cleanglow, he suggested that the quality of Gloco, insofar as its 'burnability' was concerned, was very closely related to the rate of coal throughput. In fact they had found that the Gloco quality most readily acceptable to the consumer was produced by operating retorts at maximum possible coal throughput.

He agreed with the authors' statement that in smoke control areas the majority of householders preferred to use one or other of the solid smokeless fuels in order to comply with the requirements of living in a clean air zone. A number of householders in the Eastern Board's area were using the higher priced premium fuels such as Cleanglow, although Gloco was steadily gaining favour particularly in the new towns; price appeared to be a minor factor and the average housewife willingly paid a little extra for a quality fuel.

His experience, too, was that the demand for Cleanglow was well in excess of output and, in fact, the new carbonising plant at St. Albans works had been turned over to the production of Cleanglow last October. The whole output of approximately 1,500 tons per week had been sold and, since the end of November last, it had been sold as fast as it could be produced.

With energetic marketing, backed by the right quality product—*a most important requirement*—there should be good opportunities for the continued development of the industry's solid fuels in the domestic market.

There were, however, two small clouds on the horizon—the availability of adequate supplies of coal of the right qualities for the production of both Cleanglow and Gloco, and the industry's forward production programme visualising a steady reduction in the availability of its solid fuels. It was difficult to believe that greater quantities of suitable coals could not be found among the large tonnage of around 28 mill. tons, now going into the house coal market. Forward production was already a matter of economics since the industry must produce gas as cheaply as possible if it was to hold its own, let alone expand.

Price and production

The justification of continued production of solid fuels by the industry would obviously depend upon the price which could be obtained for these fuels and the price paid for the coals from which they were produced. He believed that higher prices could and would be obtained for the industry's solid fuels, but he had to emphasise once more that such additional prices could only be achieved if production standards were maintained.

Mr. W. P. Smith, East Midlands Gas Board, Derby, said that in his Board it had been the normal practice for several years to carbonise East Midlands' 501 and 601 coals at the maximum throughput, and therefore the same percentage increase in throughput shown in the paper could not be expected, but even so 11.48 tons per retort per day had not yet been attained at Nottingham, where the setting was similar to that at Bow Common. With steaming at about 12% of the coal carbonised on the 81-in. W-D lambent heated retorts at Nottingham, the figure quoted in the paper of about 6% in the North Thames Gas Board was of considerable interest.

The declared calorific value at Nottingham was 480 B.t.u. per cu.ft., and additional producer gas plant had been under consideration to enable a still higher increase in the throughput to be made while maintaining the required calorific value. This plant had been held in abeyance since there was the possibility of increasing the declared calorific value.

Referring to the need for continual and careful supervision of coke discharges being essential, he asked whether there was constant technical supervision during the draw periods or whether the supervision was exercised by foremen or charge hands. He assumed that the high throughputs made necessary a reduction in the period between draws, and asked the authors to confirm this and to give the time between draws at Bow Common. Increased throughput and low steaming suggested more scurf production, and he wanted to know whether this in fact occurred and, if so, to what extent.

On the subject of mixing of the coals, Mr. Smith asked the authors whether any special precautions were taken to avoid some retorts getting all the coals of 1½-swelling number and others all the coals of 3½-swelling number over one 24 hours and the reverse happening during the next 24 hours.

To increase the availability of coals—normally 1½ to 2½ swelling numbers—his Board had introduced a coal with a swelling number of 3½. This had caused variable retort travel and produced an undue proportion of over 2-in size. To overcome this, in addition to marshalling of wagons in the predetermined proportions, arrangements were being made for the shuttle belt above the coal bunkers to travel continuously backward and forward over the full length of the bunkers in an effort to effect mixing by layering.

Referring to the importance of sizing, he quoted a recent series of tests by hand screening of run of retort Cleanglow over 1-in., 1¼-in., and 1½-in. screens respectively, in which the 1½-in. screening had given the best performance on ignition and third-peak test. Each works had evolved screen sizes most suitable to the types and sizes of coal carbonised, and he asked the authors to state the main screen and debreezing screen sizes used at Bow Common. Personally he had found that an undue proportion of material below 1-in. materially affected ignition and the speed of recovery after reloading.

In a written contribution **Mr. J. B. Leaman,** Coke Marketing Officer, East Midlands Gas Board, said that no two Boards were alike, neither were their solid fuel markets. Just as London itself was unique, so was its fuel market. In introducing a premium fuel into the East Midlands market there had been somewhat different problems to face. Unlike London, their very foundations were in coal, and with substantial quantities of concessionary coal supplied to many thousands of miners in a number of the Board's main areas of population, most local authorities had been slow off the mark in the implementation of the Clean Air Act. Again, except in Sheffield and Rotherham, the production of coke was of a good quality continuous vertical variety made predominantly from East Midlands coals and matching up to Gloco standards.

Experience showed an increasing demand for continuous vertical coke as an open fire fuel, despite its alleged unpopularity with the general public. A recent market survey of one of the largest individual smokeless zones—as opposed to smoke controlled areas—under the Act, confirmed the satisfaction of the residents with the locally produced vertical coke.

Much of the East Midlands too had a low density of population, so in view of the impracticability of fully absorbing the production of Cleanglow locally in established continuous vertical coke markets, they had had to face the necessity of selling it in small quantities throughout the whole of the area, in some instances involving high carriage charges. It was, therefore, not until some 15 months ago that his Board had considered the time opportune for the introduction of a premium fuel.

Exclusive handling

Since Cleanglow would be sold mainly in place of coal, his own Board too had decided to give the distributive trade the opportunity of handling Cleanglow exclusively, a decision which they had not regretted.

Conditions in Sheffield, because of its heavy industry and its difficult smog problem, were somewhat parallel to those in many parts of London, in that the locally produced horizontal and intermittent cokes were not perhaps the most suitable fuel to offer to new consumers who were traditionally used to the comparative ease of burning coal. It was therefore perhaps significant that about half the sales of Cleanglow were to merchants in the City of Sheffield and its environs, and many merchants were now selling it as their No. 1 fuel to the smoke control areas in that city.

Unlike the area boards in the South of England, their main competitors were the established premium fuels, produced in the centre of their area and sold at comparatively low prices because of lower transport charges. Prices for Cleanglow must therefore be dovetailed into those of their competitors, rather than to tie the price structure to that for coke by the simple addition of a premium.

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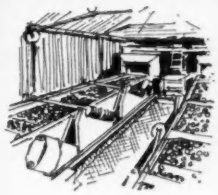

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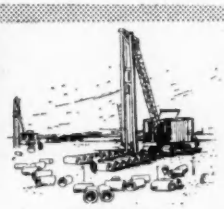

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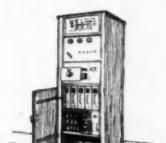

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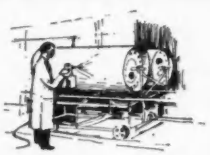

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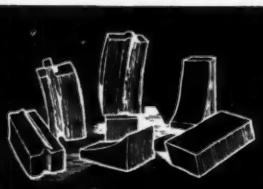

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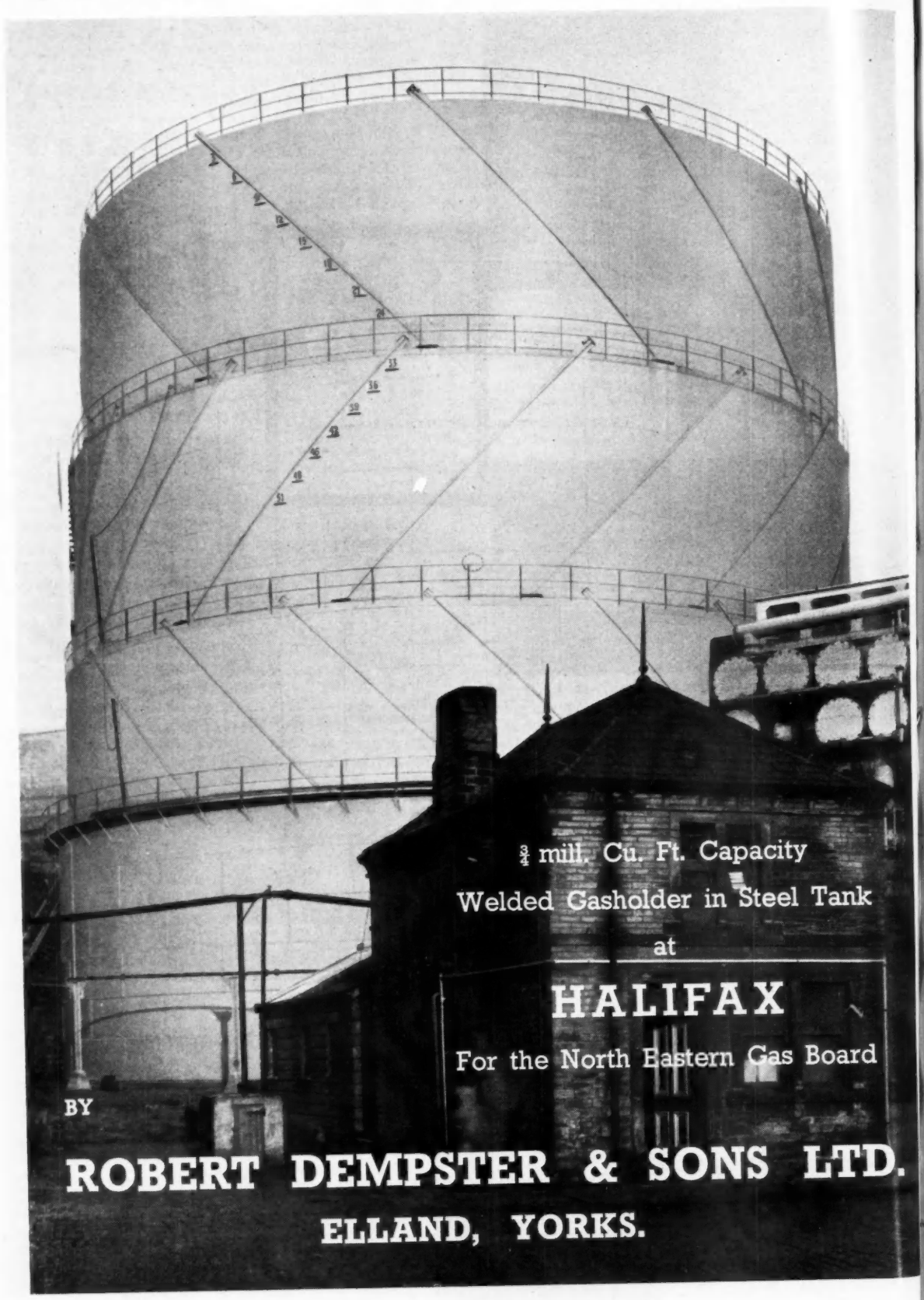
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In the first 12 months only some 10% of the merchants —18% in Sheffield—would handle Cleanglow, but the position had now improved and sales had quadrupled, so that the present demand exceeded the supply. The Board was now marketing to twice as many merchants and the gospel of Cleanglow was spreading. Fortunately, the North Thames had been able to assist with orders and that Board had been most helpful and encouraging throughout.

Though generally speaking it did not seem that Cleanglow would become the automatic choice of the regular domestic coke user, as the number of clean air zones continued to grow sales of Cleanglow would increase as well. Coke of the Gloco type and Cleanglow would each find its own market, since experience had shown that the increased sales of Cleanglow had not been at the expense of vertical coke.

Finally, Mr. Leaman asked with what success had the development of a stable market been achieved for Cleanglow in the 'country' districts of the North Thames Board's area.

Dust nuisance

Mr. F. Dawson, Station Engineer, Lea Bridge, N.T.G.B., said that at his works dust had been a major nuisance, so it had been essential to quench the coke as quickly as possible. The fuel discharged from the chambers was pretty hot and water had to be literally poured on to it. It was impossible to use a wetting agent at that point, so it might be just as well to use water initially. When the temperature of the coke had fallen to a reasonable degree, the wetting agent could be usefully applied. The fuel was stored in a buffer hopper until most of the steam had disappeared and the coke sufficiently cool for further treatment.

The increased throughputs of 50 to 60% put a big strain on the works if it had not been designed for it. The producer fuel consumed per day was almost exactly the same as with the former throughput of 4.7 tons per day, though it had now increased up to 7 tons per day. This was contrary to the experience at St. Albans. Though operating conditions might be similar heat required for carbonisation must be less, so conditions within the retort must be different.

Mr. Dawson suggested that by blending non-swelling coals with a swelling coal an increased throughput by 10% might be possible, which would show a considerable saving in money.

Mr. Arnold Marsh, Director, National Society for Clean Air, said this fuel was what they had been waiting and hoping for. The Beaver Committee urged a big increase in the consumption of all types of smokeless fuels within the next ten to 15 years; in practice the greater part of the change must be to solid smokeless fuel. Education, however, was necessary for those living willy-nilly in smokeless zones, and such fuels were a great assistance to all such people. Cleanglow was clearly something better than what had always been the main solid smokeless fuel, coke, and he hoped the gas industry would double its efforts to increase production of Cleanglow and even quadruple them in the production of Gloco.

People were now preferring the better quality fuel; their opposition in the past to coke had been based partly on experience and partly on its misuse in the wrong type of appliance.

Mr. Marsh pointed out that those interested in clean air were a little concerned about the adverse publicity that cropped up from time to time. It was undoing a great deal of good work in spite of the great efforts made by all concerned. The gas industry, he thought, should counter this bad publicity, which occurred all too often as 'human' stories in the local Press.

The Peach Committee had changed the name of such fuels to 'specialist reactive fuels.' Mr. Marsh was disturbed that the prefix 'premium' was still used, and thought that some other, less discriminatory word could well be substituted for it.

Mr. Cunnold, replying to the discussion, said that the experience of Mr. Garner at St. Albans closely followed the pattern of theirs in the North Thames; his increase in throughput was similar to their own. Mr. Deas has mentioned low third peaks and the reaction of the customer to this. He would agree that probably too much stress was put upon this radiant heat value; the customer, after relighting the fire, gave it a good poke, and paid no attention to low third peaks.

With regard to the suggestion of specifying the absence of shale in the coal to be carbonised, he thought there was enough in the specification already. The coals used for the manufacture of Cleanglow did contain a proportion of what appears to be shale, which was in fact a proportion of 'top hards.' Though this burnt well, it left a shale-like residue in the fire. He had never seen any stones in Cleanglow.

In answer to Mr. Smith, he agreed that the throughput he quoted was understandably lower because of the lower rank coal to that used by the North Thames, but steaming at 12% was abnormally high and would restrict throughput. He considered producer gas dilution to a c.v. of 480 more satisfactory than a high rate of steaming.

Supervision was very important, and the foreman, assisted by the shift superintendent, checked the extraction of the Cleanglow; this in fact did put additional work on him; the number of draws had been increased from four to even five. There has been no increase in the labour force, but it has been redistributed.

Extended scurfing period

The scurfing period had been extended, but the amount was not very different; its character, however, was softer and more easily removed. In some cases the scurfing period extended by as much as 20%. There was no mixing of coals; they were loaded into the bunkers as they arrived. This did upset carbonising conditions, which was why they must be carefully supervised. Scurfing temperatures were rigidly controlled, and the upward method of scurfing was employed with the central aim of reducing them to a minimum.

In reply to Mr. Dawson, he pointed out that the blending of coals with other materials was very difficult to carry out, and was quite expensive, but the real difficulty was one of getting a reasonable homogeneous mixture.

Mr. Rose, replying, said that during the first year their feet had been pretty cold, but the Board had stood by them. The East Midlands had had some of the same teething troubles at Derby and now at Nottingham. There was no one solution because the coke markets of no two boards were alike, and what went for one did not necessarily go for the other.

Mr. Leaman had asked about the sales of Cleanglow in rural areas. The distribution of Cleanglow extended to the west of London and into Essex, and it had been equally successful there as in the towns.

In reply to Mr. Marsh's comments upon the term premium fuel, the term had been taken over ready made. It had been used to describe the burning properties of the fuel, but now it was just called Cleanglow.

Some economic aspects of underground l.p.g. storage

By PETER W. SHERWOOD,
RESEARCH ENGINEER, NEW YORK.

UNDERGROUND storage of l.p.g. products serves the following major types of operation: At the producing plant or at wholesale outlets where l.p.g. must be stocked as sales inventory; at very large consumer plants; at large local distribution terminals; as emergency surge capacity for pipelines; and at gas utility stations where l.p.g. is stored as stand-by or peak demand fuel and to even out the very large seasonal fluctuation in l.p.g. demand which cannot be economically absorbed by the transportation system.

Thus, underground storage of l.p.g. is a way of providing propane-butane inventory and of storing transportation. The latter concept is utilised by pipelines which must operate at a fairly high percentage of capacity throughout the year and must thus resort to storage of product delivered to the market area during the summer months to meet requirements for l.p.g. in winter.

Thus, the growth of gas pipelines in the U.S. and Canada has been accompanied by unprecedented expansion of underground storage facilities for l.p.g. In the United States, installed capacity rose by 15% between the years 1958 and 1959 alone, while it quintupled from 9,500 mill. barrels in 1954 to 49,000 mill. barrels in 1959—a trend which is expected to continue throughout the early 1960's.

Mined caverns

It is noteworthy that much of the new growth in underground facilities has been in the form of mined caverns. While salt domes and salt layers constitute the lowest-cost strata for building underground mines, their use is limited by unavailability in many l.p.g.-consuming areas and thus recourse must be had to constructing mined underground cavities. At the same time, the use of oil, gas, and water sands for l.p.g. storage has experienced a relative decline in importance as the function of 'transportation storage' has become more significant than the accumulation of inventory at the production source where such porous formations are available.

The relative importance of the various types of underground strata for l.p.g. storage is summarised in Table I.[1, 2]

TABLE I

	Percentage of installed capacity	
	1957	1959
Salt domes and salt layers	75·1	82·9
Mined caverns	3·2	9·2
Oil, gas, and water sands	18·2	7·3
Miscellaneous (existing cavities, abandoned mines, etc.)	3·5	0·6

Along with this general overall trend, there has been a movement toward larger individual storage installation. The largest single present underground storage facilities are, of course, washed out of salt domes in which incremented capacity can often be built at extremely low cost. Some of the largest such installations are operated by the Texas Butediene & Chemical Corporation—1.7 mill. barrels in one cavity—the Phillips Petroleum Company—3.4 mill. barrels in five caverns at Hutchinson, Texas, 1.5 mill. barrels in three caverns at Brazoria, Texas, and the Warren Petroleum Company—3.6 mill. barrels in one cavern.

In the case of mined caverns, maximum sizes are very much smaller—the limit to date in the 200,000 to 250,000 barrels range. Occasional very large capacity is utilised in oil sands, e.g., 1.2 mill. barrels in an installation of the Shamrock Oil & Gas Corporation, Moore, Texas.

In general, underground storage of l.p.g. is economically only applicable to installations of fairly large capacity. For smaller capacity, units of this type must be excavated in comparison with pressure tanks and refrigerated storage.

On grounds of safety, underground storage has a clear advantage. In case of leakage from underground, only a relatively small amount of the gas is released. Flow of gas is cut off as soon as the displacement brine column falls enough to be balanced by hydrocarbon pressure in the release line and the underground l.p.g. liquid is cooled sufficiently by vaporisation.

From the point of view of location, too, underground storage has the advantage that there is not much visible above-ground equipment. It is therefore acceptable in many residential areas, whereas use of pressure tanks and refrigerated storage is restricted to industrial areas. On the other hand, underground storage imposes specific geological requirements on possible location, and this aspect will now be considered.

Investment costs

Investment costs in various types of l.p.g. storage—underground storage, pressure tanks, refrigerated—have been investigated by Tucker[3] with the following conclusions:

Small units (say 15,000 barrels or less) are most favourably built as conventional horizontal pressure tanks. For units above 30,000 barrels, refrigeration is indicated in above-ground service, and here very large volumes (250,000 barrels) employ most suitably deeply refrigerated dome-roof (atmospheric pressure) tanks. Intermediate volumes may be either dome-roof or refrigerated pressure spheres and here the selection of optimum design depends on required storage volume, climate, utilities cost, throughput and filling rates.

Compared to underground installations, refrigerated storage is clearly more suitable for small installations. For propane, underground storage becomes more favourable at the following approximate capacities: 30,000 barrels in salt caverns, or 100,000 barrels in mined caverns. It is noteworthy that the cost advantages of mined caverns of above-ground refrigerated storage is small at best, and that it disappears at very large storage capacities—5 mill. barrels or more.

In the case of butane storage, Tucker estimates that the investment cost in mined caverns is greater than in refrigerated tanks, regardless of capacity. On the other hand, salt caverns show substantially lower investment than refrigerated storage for capacities above 30,000 to 40,000 barrels. In any case, however, refrigerated storage incurs higher operating costs than underground storage. On an out-of-pocket basis, these costs are in the range 5-20% per barrel per year for the most economical type of refrigerated storage applicable to a given service.

Propane storing

On a book basis, the operating costs of storing propane show the following relative position: Below 70,000-gal. capacity, pressure tanks are most advantageous; in the range 100,000 to 5 mill. gal., the preference goes to refrigerated storage. Above this value, best cost performance is shown by underground storage[4].

There are four general methods by which underground caverns for l.p.g. storage can be constructed.

1. Dissolve out salt deposits by leaching with water
2. Create a cavity by conventional mining methods
3. Utilise existing porous formations, such as depleted oil reservoirs, gas, or water sands
4. Utilise existing cavities such as caves, abandoned mines or tunnels.

The relative importance, on a capacity basis, of these different kinds of structure is shown in Table 1.

Use of existing cavities and injection into depleted oil deposits, is limited to the locations where such facilities happen to exist. Porous formations are found especially in oil and gas fields, rather than in the product markets. Thus, these may provide inventory capacity but not 'transportation storage.' Furthermore, injection of l.p.g. into depleted oil reservoirs is accompanied by high product loss.

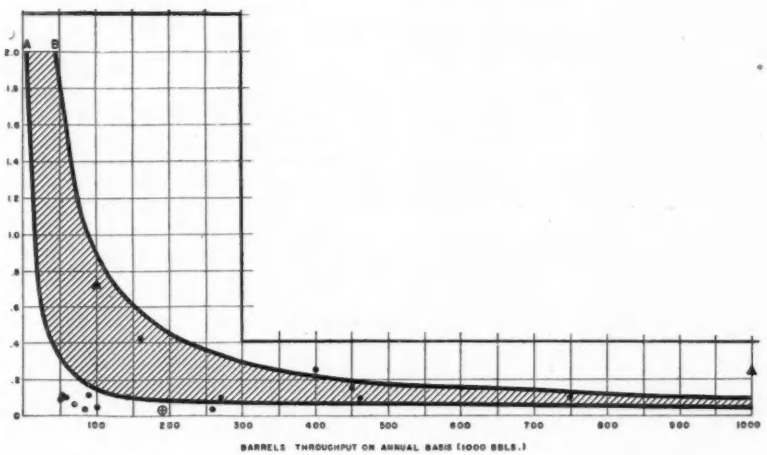
Large salt deposits

Salt cavities are also limited to locations where suitable formations exist; however, where large salt deposits are available, they offer an opportunity for constructing very low-cost large cavities.

Of salt strata, salt domes are easier to work with than salt beds because intermediate layers of other materials are usually not found. However, other types of formation are often also satisfactory.

Mined cavities are the most expensive form of underground storage. Nevertheless, they are still justified by the incentive for storing l.p.g. products at refineries as well as in the area of the market in locations where suitable salt structures are not available.

Rock for mined caverns must be structurally strong, relatively homogeneous, unfractured, massive, inert, impervious, and the stratum must be at a depth defined by storage pressure—one foot overburden per lb. per sq. in. gauge maximum operating pressure; minimum depth is 200 ft. for propane, 100 ft. for butane to assure adequate



This graph shows out-of-pocket operating costs per barrel throughput (hypothetical). Key: Curve A 100,000-barrel terminal, two men, one tour, 40-hour week 1% O.T. tank car and tank truck unloading, tank truck loading out only. Curve B—750,000-barrel terminal, five men and superintendent, three tours, 40-hour week (seven-day week) and 1% O.T. tank car, tank truck and pipeline receipts and shipments. Curves plotted for solution type storage but approximately true for mined storage. Plotted 'out-of-pocket operating costs' from questionnaires are for storage units located at, and operated by, producing plant. Costs quoted without breakdown and cannot be compared. Bold dots signify solution; pyramids signify mined; cross in circle, depleted oil or gas sands, stratigraphic traps etc.; graph shows vertically cost per barrel throughput (dollars) and horizontally, barrels throughput on annual basis (1,000 barrels).

roof strength. The most important types of rock suitable for caverns in l.p.g. storage service are salt, shale, siltstone, chalk, limestone, granite, and gneiss.

The cost of a cavern increases with depth and operating problems occur when the temperature of the bottom formation exceeds 100°F. Thus, the limiting depth of the cavity is about 4,000 ft.

In salt formations, the cost of underground caverns is influenced by the following key factors:

1. Knowledge available about the formation.
2. The method required to dispose of brine.
3. The size of the cavern, since incremental cost is very small. Kramel[5] points out that, by using fresh water instead of brine to recover the l.p.g., a 15% increase is obtained in the size of the cavern every time it is emptied and filled.

In mined underground storage, the ideal chamber shape is spherical. Actually, limited rock thickness and mechanical problems in excavation and rock removal make this shape impractical and, instead, the normal mined chamber is of modified rectangular or circular cross-sections.

Rock bed characteristics

In such caverns, the permissible size of opening depends on the physical characteristics of the rock bed. Very large cavities are occasionally possible but, in most instances, practical size of the chamber is in the range of 20 to 60 ft. both in width and height. However, the largest feasible opening is more economical than numerous small cavities of equal capacity because, in large units, the same amount of drilling will break more rock and mechanical means of rock removal can be employed more readily and more economically.

For unlined mined cavities—which includes nearly all mined l.p.g. storage—in the 50,000 to 200,000-barrels range, cost of installation is in the range $2-8 per barrel capacity[6]. Determining unit cost are the following main factors: capacity, depth, nature of rock, mining methods, type of permanent installation, location cost of labour and supplies.

Time for constructing a mined cavern is considerably in excess of the schedule for salt cavities. Assuming a smooth schedule, however, total time required for construction of a 200,000-barrel mined cavern is 19 months[7]. This includes preliminary studies and site selection (3 months), site investigation (3 months) and detailed design (one month). Actual construction and mining time is 11 to 12 months.

Brine injection

In any type of underground storage, l.p.g. is received in the normal manner by pipeline, tank car, barge, or tank truck. The product is removed from the cavern, as needed, by injection of brine—salt caverns—or water, or by pumping methods. Especially when water displacement is employed, a simple after-processing step is often required—such as water knockout, l.p.g. dehydration, and possibly even refractionation.

The unrecoverable product depends on the type of construction. It is reported[2] to be 2 to 10% for solution-type —washed salt deposits—chambers and 0 to 2% for mined cavities. In depleted oil deposits, loss may be very high (2 to 50%) and much of the product must be handled in gaseous form. Out-of-pocket cost of operating various types of underground storage systems are illustrated in the diagram.[2]

Once the need for underground storage in a given locale has been established on an economical basis, specific site selection is undertaken. Here, the guiding considerations are concerned with geologic aspects of the entire zone from the surface through the depth in which the cavern is to be developed. In addition, consideration must be given to the following auxiliary aspects: availability of transportation facilities and utilities—including adequate water supply—means of waste disposal—and possibly brine retention—proximity of conflicting operations, and surface conditions.

The National Petroleum Council of the U.S.A. has investigated these key controlling factors in site selection, and its conclusions may be summarised thus:

Geological considerations. 1. Storage depth must be adequate to insure sufficient strength of the overburden to contain the stored product at its maximum pressure. However, excessive depth is responsible for high construction and operating cost. Tentative standards by the Natural Gasoline Association of America call for 1 ft. overburden per lb. per sq.in. maximum operating pressure.

2. Caverns in salt deposits are generally deeper than mined storage facilities since, in the latter, lateral shafts become part of the storage capacity. Vertical height in salt beds is limited only by the thickness of the salt section. Typical height of l.p.g. caverns on such formations ranges from 100 to 1,000 ft.

3. An impervious storage zone is required to confine the product. In the case of porous zones, the product must be confined by the overlying and underlying formations.

4. Foreign materials, such as sulphur and gas, should be absent. In site selection, attention must be paid to geological faults in the cavern through which such contaminants might enter.

5. Structural strength of side walls, roof, and base of the cavern must be adequate.

Technical points

Auxiliary technical considerations. 1. Adequate transportation facilities—pipeline, waterways, railroad, highways—must be accessible to the cavern site.

2. Adequate electricity and fuel must be available to operate auxiliary equipment. Of much importance, in the case of salt caverns, is water supply. In active caverns, total water consumption normally ranges from seven to ten times the salt cavern capacity; minimum daily requirement during the leaching operation is about 5,000 barrels of water per day for each active cavern.

3. Facilities must be at hand to dispose of the brine formed during leaching of salt caverns or the spoils formed in the course of mining operations. In the case of salt caverns, it is also generally necessary to provide storage space for brine which is to be used for production displacement in the cavern's day-by-day operation.

Any underground storage facility for l.p.g . products must be protected from overpressurising by means of relief valves on the filling line or well head casing. Automatic shutdown devices or alarms should be provided to prevent accidental overflowing of the cavern.

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NEWS SUPPLEMENT

PAY QUESTION

WHEN the Minister of Transport, Mr. Ernest Marples, told the House of Commons of the decision to appoint Dr. Richard Beeching as Chairman-designate of the new Railways Board, at a salary of £24,000 a year, Mr. G. R. Strauss (Lab., Vauxhall) asked whether in view of this appointment and the very high salary to be paid, it was the Government's policy to pay similar high salaries to the chairmen of other nationalised industries, which were also of great importance, or was this an exception?

Mr. Marples replied: 'There may be one or two other special appointments, but there will be no change in the Government's general policy on salaries of members of the boards of nationalised industries.'

Dr. Beeching is to be paid the same salary as he is receiving from Imperial Chemical Industries Ltd., by whom he is being released for a period of five years.

Power Minister sees plant for Cleanglow

THE Minister of Power, the Hon. Richard Wood, visited the St. Albans works of Eastern Gas Board on March 3 and, in particular, was shown the new carbonising plant which is producing Cleanglow.

This was the Minister's third visit to Eastern area and his second recently.

He was entertained to lunch at Radiant House, Watford, on January 26 by Mr. J. H. Dyde, Chairman; Mr. F. T. Brookes, Deputy Chairman; members and officials of the Board.

As he was unable to visit the new plant at St. Albans on that occasion he promised to return, and for the return visit he had the company of Mrs. Wood. The Board Chairman was accompanied by Mrs. Dyde.

The Minister took a keen interest in the plant and met many of the supervisory personnel at the works.

His first visit to Eastern area, and his first to a gasworks after his appointment as Minister, was to Willoughby Lane, Tottenham, in 1959.

Gibraltar pipeline may bring Saharan natural gas into Europe

A PROPOSAL is believed to have been put forward to the French authorities by British Insulated Callender's Cables for the installation of a flexible submarine pipeline across the Mediterranean. Its purpose would be to carry Saharan natural gas to Europe, says the industrial correspondent of the *Financial Times*.

It is understood that the route proposed would be across the Straits of Gibraltar, close to the route chosen by SEGANS, the study group set up by the French Saharan producer companies.

This route has the advantage of a short sea crossing, but it involves the construction of a long pipeline from the Hassi R'Mel deposit through Morocco.

The chief interest in the latest proposal is that British Insulated Callender's Cables is the only manufacturer currently able to make and instal a flexible pipeline for carrying natural gas.

—OR WILL THERE BE TWO ROUTES?

THE prospect of Soviet-bloc natural gas reaching Western European markets sooner or later was referred to in a talk by M. de Corval, research director of COMES, the sales company for Sahara natural gas, says a Paris message in the *Financial Times*.

He estimated that the total investment involved in extracting the Sahara gas and piping it to Europe would be around $1,000m.

This would give Western Europe an extra 13m. to 15m. tons of coal-equivalent extra energy supplies each year.

For other forms of energy the same investment yielded an average of only an extra 5m. tons a year coal-equivalent.

The gas pipelines would have to pass through Morocco and Spain, on the one hand, and Tunisia and Southern Italy, on the other.

They would thus bring energy supplies to areas that had hitherto lacked them.

M. de Corval's remarks suggest that COMES is thinking, in the long term, of using both the Spanish and the Italian routes for piping its gas to the industrial areas of Western Europe.

But it still has to decide which pipeline to lay first.

TECHNOLOGICAL AWARD

Mr. M. N. Lawrence has been awarded a Diploma in Technology in Applied Physics by the National Council for Technological Awards. Mr. Lawrence, of the Birmingham College of Advanced Technology, underwent industrial training with the West Midlands Gas Board.

Normal working has been resumed at the 11 pits in the Doncaster area after the fortnight-old strike called by the unofficial Doncaster Miners' Panel.

ROYAL BUYER

The Princess Royal visited the Gas Pavilion at the Ideal Home Exhibition. What she required was a large cooker—something with about six burners on the hotplate. The party was escorted to Radiation stand where a cooker met requirements and an order was promptly placed. The cooker is for the London home of the Princess.

PERSONAL NOTES

MR. J. SOLBETT and MR. LENNON have been appointed Associate Directors of Humphreys & Glasgow Ltd. of London. Mr. Solbett was with Simon Carves Ltd. for a number of years. He joined Humphreys & Glasgow in September, 1956, as senior chemical engineer, and was appointed chief chemical engineer in June, 1959. Mr. Lennon joined the company in July, 1957, as a senior chemical sales engineer and was stationed in Milan for some time. In May, 1959, he was appointed a director of Humphreys & Glasgow's French associate company—Société de Construction d'Appareils pour Gaz à l'Eau et Gaz Industriels.

MR. R. M. CADDICK has been appointed to the Board of W. J. Jenkins & Co. Ltd.

MR. D. C. M. SALT has been appointed a member of the Board of Monsanto Chemicals Ltd. Mr. Salt, who joined Monsanto in 1935, has wide experience and knowledge of the Company's sales activities. He has been Director of Sales since 1959 and had previously been appointed general manager of sales in 1956.

OBITUARY

MR. W. SAYNER, B.E.M., formerly group engineer with the East Midlands Gas Board, has died at his home after a long illness. He was 75 years of age and spent all his working life in the gas industry, starting with the former Grimsby Gas Company in 1903 and retiring from the East Midlands Gas Board's service in 1957. His father was also with the Grimsby Gas Company for many years.

MR. G. BRAIDWOOD, a former manager and director of Coatbridge Gas Company, has died at the age of 76. Mr. Braidwood became manager of the Coatbridge Company in 1916 and before his retirement in 1948 he was made a director. He was president of the Waverley Association of Gas Managers in 1933 and president of the annual conference of the North British Association of Gas Managers in 1938.

MR. JOHN WEBSTER, who was gas manager at Burntisland until nationalisation, has died at the age of 57. Before that he was gas manager at Lockerbie.

COMING EVENTS

April 5.—YORKSHIRE JUNIORS: Visit to William Asquith Ltd., Halifax.

Gas joins a pilot scheme for Poole

THE new Skinner Street flats—part of the redevelopment of the old area of Poole—represent both a victory and an opportunity for Mr. Therm.¶

This block of 12 flats comprises six one-bedroom homes and six with two-bedrooms, the floor areas being 511 sq.ft. and 653 sq.ft. respectively.

It was originally designed in the Borough of Poole architect's department on all-electric lines, but after negotiations by Southern Gas Board representatives it was agreed that half the flats should be allocated for gas installation.

The block is therefore being used as a pilot scheme to compare the running costs for space heating and water heating of gas and electricity.

In each of the six flats a Halcyon F.45 selective warm air heating unit provides outlets to the hall and living-room.

It is worth noting that additional outlets to the bedrooms could have been fitted at little extra cost, but that outlets were restricted to two in number so that useful comparisons could be drawn with electric under-floor heating.

Each Halcyon unit is housed in a prepared cupboard, the top half of which can be used as an airing cupboard, warmed by radiated heat from the flue and metal ducting.

Flues from the heaters are connected by asbestos flue-pipe to built-in True-Flue 'X' blocks, which terminate through the roof in a single brick stack.

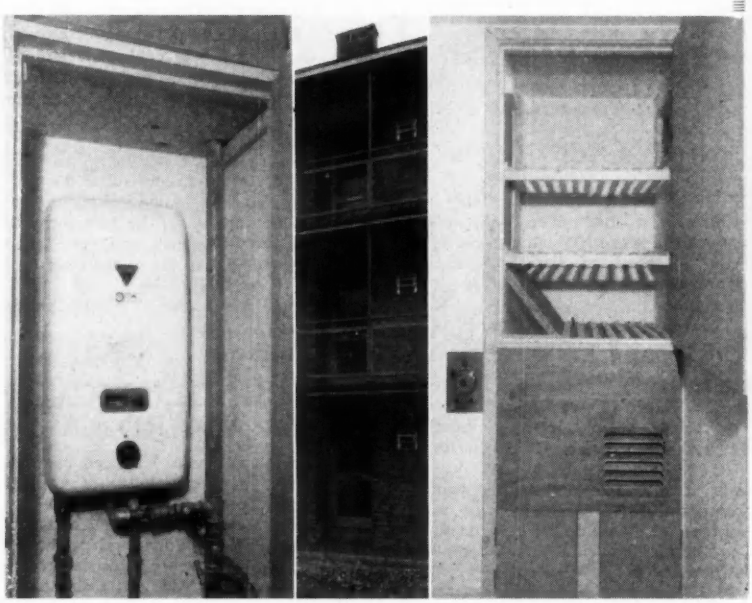
Room thermostats and clock controls provide for automatic operation, and selective heating can be obtained by operating the louvre shutters on the unobtrusive outlet grills.

Instant hot water is supplied to bath, wash-basin and sink by an Ascot 715 balanced-flue water heater.

This is fitted in a prepared cupboard in the kitchen, arranged so that the gas meter can be fitted beneath it.

The Borough of Poole architect's department housing section commented favourably on the neatness of the installations, and the compactness of the appliances for this particular building design.

They also expressed their appreciation of the way in which Southern Gas Board personnel completed their tasks with a minimum of interference to other building operations.



Left to right: An Ascot 715 balanced flue instantaneous water heater installed in a prepared cupboard. Front view of Skinner Street Flats showing balanced flue outlet terminals and brick stack through which Halcyon heater flues terminate. Completed Halcyon F.45 installation showing warm air outlet to hall and airing cupboard completed.